

## **Phase 1**

### **NEER Grant: DE-FG07-98ID13632**

**Title:** Reactor whole core transport calculations without fuel assembly homogenization

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**Co-Investigator:** Elmer Lewis, Northwestern University

The first phase of the project covers the period 9-1-98 to 8-31-99

**Objective:** To investigate alternative methods for the detailed computation of neutron flux in the core of a nuclear fission reactor.

#### **Results:**

Work continued on the 2-D form of the finite subelement formulation described in the previous progress report (report to Dr. D. Hoffer, 2-19-99). The method allows the homogenized cross sections for each fuel-pin cell to be represented explicitly in whole-core VARIANT calculations thus obviating the need for fuel assembly homogenization. It has been applied to a number of LWR problems containing MOX fuel, and compared to fine-grid VARIANT calculations in which each fuel-pin cell is represented by one node. Most recent CPU time comparisons indicate that using the subelement formulation instead of attempting to treat each fuel pin cell as a separate node results in reducing CPU time by nearly an order of magnitude. Sensitivity to surface approximations between fuel assemblies has also been investigated.

The results of this work have been reported at the June '99 ANS meeting in Boston. A reprint of the paper "Whole core comparisons of subelement and fine mesh variational nodal methods" is included. A more extensive write-up will be included in a paper entitled "Space-angle approximations in the variational nodal method" to be presented at the Sept. '99 meeting on "Mathematics and computation, Reactor Physics and Environmental Analysis in Nuclear Applications", in Madrid, Spain.

Mr. Micheal Smith, a Doctoral candidate at the University of Missouri-Rolla, is working full time on the project; this Summer (1999), Mr. Smith has moved to Argonne National Laboratory where he utilizes the facilities available there and performs his work in consultation with ANL personnel.

Under the direction of the principal investigators, Mr. Smith has become thoroughly familiar with the theory behind VARIANT. He has investigated spatially-dependent cross sections and their implementation into VARIANT. As a part of this process he has generated the integral arrays of spatial and angular basis functions, which VARIANT needs to generate the response matrices. A

separate program was written to generate these integral arrays. The arrays produced by this program were checked using an external mathematics utility and by performing several hand calculations. As was expected, the addition of spatially-dependent cross sections will result in an increase in computational time and in required data storage space. However, the magnitude of these increases is believed to be small whereas the benefits gained from the spatially-dependent cross sections will be substantial.

Currently we are examining the use of triangular finite elements to eliminate the need for fuel-moderator homogenization in whole-core calculations. We plan to first implement a one node per fuel-pin cell formulation in which fuel and moderator regions of a cell are modeled by approximately 30 triangular finite elements with spatially linear trial functions. In Phases 2 and 3, this work will be the point of departure for the examination of increasingly accurate and computationally efficient finite element formulations and for the integration of triangular finite element into the subelement methods.

By the end of Phase 1 (8-31-99), it is expected that the following two tasks will also be completed.

- (1) Demonstration of whole core calculations level using prototypical alterations of VARIANT in which homogenization is performed only at the fuel-pin cell and not at the fuel assembly. Accuracy and computational efficiency are examined by comparing finite subelement and fine-grid homogeneous-node VARIANT calculations. Findings thus far are documented in the two above cited publications.
- (2) Formulation and implementations in prototypical form of a 2-D method in which each node consists of one fuel-pin cell with the fuel-moderator interface represented explicitly with triangular finite elements, thus eliminating all homogenization. Proof of method will be demonstrated with at least one-model problem calculation.